ANSWERS: Relative concentrations of dissolved species

1. $HOCl + H_2O \rightleftharpoons OCl^- + H_3O^+$
$HOCl > H_3O^+ > OCl^- > OH^-$ or $HOCl > H_3O^+ = OCl^- > OH^-$
HOCl partially dissociates, and so the equilibrium lies to the LHS/favours the reactants; therefore HOCl is present in the greatest amounts.
H_3O^+ and OCl^- are produced in equal amounts / there is a small contribution to H_3O^+ from water therefore $H_3O^+ > OCl^-$
Because there is a relatively high $[H_3O^+]$, the $[OH^-]$ is very low (or links to K_w).

2) $HCl < CH_3NH_3Cl < CH_3NH_2$
HCl, a strong acid, reacts completely with water to form 1 mol L^{-1} H_3O^+ and hence a low pH.
$HCl + H_2O \rightarrow H_3O^+ + Cl^-$
CH_3NH_3Cl dissociates completely in water to form $CH_3NH_3^+$ and Cl^-. $CH_3NH_3^+$, a weak acid, partially reacts with water to form less than 1 mol L^{-1} H_3O^+ and hence a higher pH than HCl.
$CH_3NH_3Cl \rightarrow CH_3NH_3^+ + Cl^-$
$CH_3NH_3^+ + H_2O \rightleftharpoons CH_3NH_2 + H_3O^+$
CH_3NH_2, a weak base, partially reacts with water to form OH^- ions. So there are more OH^- ions than H_3O^+ ions and the pH is thus high.
$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$

3) a) i) $HCOOH + H_2O \rightleftharpoons HCOO^- + H_3O^+$
ii) $HCOOH > H_3O^+ \geq HCOO^- > OH^-$
Methanoic acid is a weak acid so the equilibrium favours HCOOH. Dissociation produces similar amounts of H_3O^+ and $HCOO^-$. Dissociation of $HCOO^-$ produces a small amount of OH^-/ water dissociates to form a small amount of H_3O^+ and OH^- in equal amounts and after the dissociation of HCOOH there will be slightly more H_3O^+ than $HCOO^-$.

b) HCl is a strong acid and completely dissociates into its ions. .It has a low pH due to a high $[H_3O^+]$.
NH_4Cl is an acidic salt that completely dissociates into its ions producing NH_4^+. NH_4^+ is a weak acid so partially dissociates into H_3O^+, however, although acidic its pH is not as low as HCl. The concentration of $[H_3O^+]$ is lower.
NH_3 is a weak base, its reaction with water produces only a limited amount of OH^- compared to NaOH which is a strong base and fully dissociates to produce the highest concentration of OH^- and hence the highest pH.
Conductivity relates to the number of ions in solution.

4.

$HCl(aq) + H_2O(\ell) \rightarrow Cl^-(aq) + H_3O^+(aq)$
$CH_3NH_2(\ell) + H_2O \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$
$NH_4Cl(s) \rightarrow NH_4^+(aq) + Cl^-(aq)$
$NH_4^+(aq) + H_2O \rightleftharpoons NH_3(aq) + H_3O^+(aq)$

Note: Do not accept H^+, states are not required, equation may be in part (c).

$H_3O^+ = Cl^- > OH^-$
$CH_3NH_2 > OH^- = CH_3NH_3^+ > H_3O^+$
$Cl^- > NH_4^+ > H_3O^+ = NH_3 > OH^-$

(allow inclusion of H_2O and commas in place of >)

HCl is a strong acid, so fully reacts with water to produce a high $[H_3O^+]$. pH < 7.
NH_4Cl is an acidic salt that completely dissociates into its ions producing NH_4^+ and Cl^-. NH_4^+ is a weak acid, so only partially reacts with water to produce H_3O^+. pH < 7, but higher than HCl since NH_4^+ has a lower $[H_3O^+]$ than HCl.
CH_3NH_2 is a weak base, so only partially reacts with water to produce OH^- ions. pH > 7.

Electrical conductivity relates to the concentration of mobile charged particles present. In the case of solutions, conductivity relates to the number of ions present.
Both HCl and NH_4Cl completely react with water to produce a high concentration of ions, so their conductivity will be high (and equal).
Since CH_3NH_2 is a weak base, it partially reacts with water to produce only a few ions in the solution, making it a poor electrical conductor.

5. a) NH_3 weak base
NaCl neutral
NH_4Cl weak acid
HF weak acid

b)

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ Equilibrium is to the left, so the greatest concentration of a species is NH_3. For each NH_3 that reacts equal amounts of NH_4^+ and OH^- are formed and are greater than the OH^- and H_3O^+ formed by the dissociation of water. $NH_3 > OH^- \geq NH_4^+ > H_3O^+$	$HF + H_2O \rightleftharpoons F^- + H_3O^+$ Equilibrium is to the left, so the greatest concentration of a species is HF. For each HF that reacts equal amounts of F^- and H_3O^+ are formed and are greater than the OH^- and H_3O^+ formed by the dissociation of water. $HF > H_3O^+ \geq F^- > OH^-$

6. a) $NH_4Cl(s) \rightarrow NH_4^+(aq) + Cl^-(aq)$
$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$

b) **A** = Cl^- **B** = NH_4^+ **C** / **D** = H_3O^+ / NH_3 **E** = OH^-
- NH_4^+ and Cl^- form in equal amounts from dissociation of salt in water.
- Some NH_4^+ reacts further with water so $[NH_4^+] < [Cl^-]$.
- H_3O^+ and NH_3 formed in equal amounts from the reaction of NH_4^+ with water.
- $[NH_3] \ll [NH_4^+]$, since only small amount of NH_4^+ reacts (NH_4^+ is a weak acid / small dissociation constant).
- $[OH^-] \ll [H_3O^+]$ since solution is acidic.
- $[H_3O^+] \times [OH^-] = 1 \times 10^{-14}$.

$[H_3O^+] = [NH_3]$ from NH_4^+ dissociating.

7. $NaOH \rightarrow Na^+ + OH^-$
$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$
$CH_3NH_3Cl \rightarrow CH_3NH_3^+ + Cl^-$
$CH_3NH_3^+ + H_2O \rightleftharpoons CH_3NH_2 + H_3O^+$
NaOH is a strong base and completely dissociates into its ions. Strong base, so produces more OH^- ions in solution than CH_3NH_2. pH > 7 and greater than for CH_3NH_2.
CH_3NH_2 is a weak base, so only some ions react with water to produce OH^- ions. pH > 7.
CH_3NH_3Cl is an acidic salt that completely dissociates into its ions producing $CH_3NH_3^+$.
$CH_3NH_3^+$ is a weak acid, so partially dissociates in water to produce H_3O^+ ions. So pH < 7.
Conductivity relates to the number of ions in a solution.
NaOH and CH_3NH_3Cl completely dissociate, so produce a large number of ions, so high conductivity.
CH_3NH_2 has an equilibrium reaction with water, so only a few ions are produced, so low conductivity.

8. $HOBr(aq) + H_2O \rightleftharpoons H_3O^+(aq) + OBr^-(aq)$

9. a) i) $CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$
($NH_4Cl \rightarrow NH_4^+ + Cl^-$)
$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$
ii) $CH_3NH_2 > OH^- >$ (or =) $CH_3NH_3^+ > H_3O^+$
$Cl^- > NH_4^+ > H_3O^+ >$ (or =) $NH_3 > OH^-$

b) CH_3NH_2 is a weak base and only reacts slightly with water / it is a weak base, equilibrium lies to the left/only partial dissociation.

As most aminomethane remains in the molecular state there are few ions in the solution, making it a weak electrolyte.

10) i) C
Strong acid – no acid molecules, HA, are present so acid must have completely dissociated in solution. Dilute – only a small number of solute particles compared to number present in B.

ii) A
Weak acid – particles in solution are mostly acid molecules with only a few conjugate base and hydronium ions present implying only partial dissociation. Concentrated – a large number of solute particles present in the given volume of water.

iii) D
Both the acid HA particles and its conjugate base A^- particle are present in similar quantities.

11. HCl, NH_4Cl, NaCl, NH_3, NaOH

HCl strong acid, fully dissociates giving high concentration of H_3O^+.
$HCl + H_2O \rightarrow H_3O+ + Cl^-$

NH_4Cl dissolves to give a solution of NH_4^+ and Cl^- ions. The NH_4^+ ions are weakly acidic and partially dissociate in water to give a small increase in $[H_3O^+]$.
$NH_4{}^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

NaCl dissolves to give Na^+ and Cl^- ions, but neither of these have any reaction with water so solution is neutral.

NH_3 is a weak base and reacts with water to give a small increase in the conc of OH^-, making the solution weakly alkaline.
$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

NaOH is a strong base and fully dissociates, giving a high concentration of OH^- ions.
$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

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